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COOLING PANEL FOR A SHAFT FURNACE, SHAFT FURNACE PROVIDED  
WITH COOLING PANELS OF THIS NATURE, AND A PROCESS FOR  
PRODUCING SUCH A COOLING PANEL

- 5        The invention relates firstly to a cooling panel for a shaft furnace of the type through which at least one vertical duct runs, the ends of which are connected to connection ends running transversely with respect to the plane of the cooling panel. The invention furthermore relates to a shaft furnace provided with a jacket, the jacket being provided on the inside with cooling panels of this nature. In this context, the jacket is  
10      understood to mean the metal casing of the furnace. Finally, the invention relates to a process for producing the novel cooling panels.

A standard embodiment of a shaft furnace is a blast furnace for the reduction of iron ore. However, shaft furnaces are frequently also used for other purposes. Where the following text explains the invention with reference to applications for a blast  
15      furnace, this description also comprises applications for other types of shaft furnaces.

The thermal loads imposed on the wall of a blast furnace are generally extremely high. These thermal loads may, for example, be of the order of magnitude of 250 000 W/m<sup>2</sup>. To prevent damage to the metal casing of the furnace, it is therefore necessary to provide this wall with a cooling system. One of the means which is  
20      frequently employed for this purpose is the use of so-called cooling panels. These are metal panels which are attached to the inside of the steel casing, also known as jacket or steel jacket, at least one vertical duct running through these cooling panels. These ducts are then connected to connection ends which run through the jacket. That side of the cooling panel which faces towards the inside of the furnace may be provided with  
25      recesses in which refractory bricks are fitted, in order to avoid or at least reduce direct thermal contact between the hot furnace charge and the cooling panel. Unlined cooling panels are also used, however, in which case the cooling panel is cooled so intensively that a solidified crust is formed against them. This solidified crust consists of slag constituents and constituents of the charge inside the furnace.

30       Traditionally, cooling panels are made from cast iron. However, it has been found that cast iron panels can lead to problems if the refractory lining becomes worn or if parts of the crust break or melt off. Specifically, a sudden increase in the thermal load on the cooling panel, partially owing to structural changes in the material of the cooling panel, may give rise to deformation of the cooling panel and movements thereof which, 35      especially if they are repeated a number of times, may lead to cracks and leaks in the water ducts. To some extent, leaks of this nature can be avoided by closing off ducts. If there are a number of leaks, it may be necessary to shut down the furnace and carry out emergency repairs.

Previously, it has been proposed to reduce these drawbacks by casting the cooling panels not from cast iron but from copper. Due to the better thermal conductivity of copper, such a panel can tolerate higher thermal loads, while temperature differences within the cooling panel are lower. Consequently, this also reduces the risk of leaks and cracking in the cooling panel. Nevertheless, it has been found that even with cast copper cooling panels problems may arise in the long term, inter alia as a result of fatigue phenomena in the material and owing to casting defects present in cast copper cooling panels. In US 4,382,585, it is proposed to eliminate these drawbacks by producing a cooling panel not by casting copper, but rather by machining a thick rolled or forged copper sheet. In this case, the ducts are drilled through this sheet and in some cases blocked again at the ends. This design has also proven to have drawbacks. Blocking the ends of the ducts may again lead to leakage. Also, the shape of such cooling panels is limited owing to the way in which they are produced. A profiled surface on the furnace side can only be achieved at high cost, while the drilling of long ducts limits the length of the cooling panels. Generally, one drawback of the known copper cooling panels is that the connection ends also consist of copper. In many cases, copper is too soft to make mechanical connections for the cooling panels.

Therefore, there is a need for a cooling panel which consists predominantly of copper and does not have the drawbacks described. Moreover, this cooling panel is to be of a form which reduces the thermal loads and allows a stable crust to form, providing additional protection and thermal insulation for the cooling panel.

It has been found that such a cooling panel according to the invention can be obtained if, in this cooling panel, each duct and the connection ends are formed from a continuous tube made from a material selected from the group consisting of low-carbon steel, stainless steel and an alloy which predominantly comprises Cu and Ni with an Ni content of  $\geq 28\%$  by weight, and the remainder of the cooling panel consists of copper which is cast around this tube, the cooling panel being provided, on the side remote from the connection ends, with a multiplicity of horizontal ribs. Preferably the ribs have a length, in the width direction of the cooling panel which is smaller than the width of the cooling panel.

More preferably the ribs have a length in the said width direction of the cooling panel of  $\leq 50\%$ , preferably  $\leq 25\%$  of the width of the cooling panel. The copper/nickel alloy as described has a higher melting point than copper, with the result that the copper body of the cooling panel can be cast around these tubes without the tube itself also melting. It has proven possible to form copper-nickel alloys with a high nickel content into high-quality tubes which are generally used for heat-exchanger pipes under exacting mechanical, thermal and chemical conditions. Even if the cast copper body begins to exhibit pores or cracks, there will still be no leakage of water owing to the

high quality of the tube used. By furthermore providing the cooling panel with ribs on the side facing towards the furnace content, spaces are formed between these ribs, in which spaces a crust can form. The crust can consist of slag, ore, iron or a mixture thereof. Also, the crust can have been prepared by applying refractory bricks, concrete or masses between the ribs. If the ribs taper, that means that the heat flux to the main body of the cooling panel is reduced, which is of benefit to the durability of the cooling panel. By positioning a plurality of ribs next to one another on the cooling panel and making them short, it is also possible to avoid high thermal stresses in these ribs, so that they themselves also have a longer service life.

10 However, according to the invention, the ribs may also be shaped such that they thicken towards their free ends remote from the main body of the cooling panel. This prevents the loosening of the crust from within the ribs, which guarantees an extra protection of the cooling panel.

15 It should be noted that US patent No. 3,853,309 has disclosed a water-cooled blowing nozzle in which a copper/nickel tube is also cast in copper over part of its length. However, the use of blowing nozzles in a blast furnace in technical terms relates to a completely different problem from that of cooling a furnace wall with the aid of cooling panels.

20 According to the invention, an alloy which contains between 65 and 70% by weight Ni, approx. 3% by weight Fe and  $\leq$  1% of one or more of the elements Mn, Si and C has proven to be a particularly suitable material for the continuous tube according to the invention. The use of Monel, which has a composition of approx. 28% Cu, 68% Ni, 3% Fe, 1% Mn and low Si and/or C contents, is particularly preferred.

25 An important function of the ribs is that they allow a crust to form on the surface of the cooling panel, and in particular they are also able to hold this crust in place. The latter factor is also of undoubted importance in view of the fact that the charge which is moving continuously down the blast furnace exerts a high frictional force on the wall and thus, in particular, on the crust formed. Ultimately, a large part of this frictional force is absorbed by the ribs, which thereby run the risk of becoming damaged. To 30 ensure that these ribs are well able to withstand this frictional force, it has proven highly advantageous, according to the invention, to provide these ribs with supporting backs. These supporting backs ensure that the vertical load imposed is better absorbed and distributed by the cooling panel. As a result, the risk of the ribs being deformed, breaking off or being damaged in some other way is reduced.

35 In a first embodiment of these ribs with a supporting back, each of the ribs with a supporting back is T-shaped in cross section, parallel to the plane of the cooling panel. According to another embodiment, each of the ribs with supporting backs has a cross section in the shape of a +, parallel to the plane of the cooling panel.

At locations where the frictional force of the falling charge may be extremely high, it may be advisable to provide the ribs with a plurality of supporting backs. According to one possible embodiment according to the invention, for this purpose the ribs are provided with supporting backs on either side in the vicinity of their ends.

5 Copper as a material for cooling panels is considerably more expensive than cast iron. However, owing to the much better thermal conductivity of copper than that of iron, it has proven possible to save considerable amounts of material through the shape of the cooling panel. In one possible embodiment of the cooling panel, for this purpose the wall is provided with undulating recesses on the side of the connection ends, on  
10 either side of each duct, in which recesses reinforcing walls which fill up the recesses are distributed over the height of the cooling panel. Despite the fact that the cooling panel has consequently been locally thinned, it remains sufficiently strong. Optionally in combination with these undulating recesses on the side of the connection ends, it has also proven possible, in another embodiment of the cooling panel according to the  
15 invention, to provide the wall on the side remote from the connection ends with undulating recesses on either side of each duct. This also allows considerable amounts of material to be saved.

In addition to the cooling panel described, the invention also relates to a shaft furnace provided with a jacket which on the inside is at least partially provided with the  
20 cooling panels described above.

Finally, the invention also relates to a process for producing a cooling panel of one of the types described above. This process is characterized in that the continuous tube (or tubes) is firstly given its final shape, after which the copper for the cooling-panel body to be formed is cast around it at a temperature which is so close to the  
25 melting point of the tube material that, after the cast material has cooled, it is attached to the tube material. This method results in there being virtually no resistance to the passage of heat between the continuous tube and the surrounding copper of the cooling panel. In this context, it should be noted that the term copper is to be understood as meaning not only completely pure copper but also low alloy copper with a composition such as that which is customarily used for the production of copper cooling panels.  
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The invention will now be explained with reference to a number of diagrammatic figures.

Fig. 1 shows a longitudinal section through a cooling panel.

Fig. 2 shows a detail of this panel on an enlarged scale.

35 Fig. 3 shows part of a cross section through the cooling panel shown in Fig. 1, on an enlarged scale.

Fig. 4 shows a perspective view illustrating the detail from Fig. 2.

Fig. 5 shows a possible configuration of ribs with supporting backs.

Fig. 6 shows smaller ribs in larger numbers.

Fig. 7 shows ribs with additional supporting backs.

Fig. 8 shows yet another configuration of the ribs with supporting backs.

In Figs. 1 and 3, (1) denotes the steel casing of a blast furnace (the so-called jacket). A cast copper cooling panel body is denoted by (2), through which a cast-in tube (3) runs. This tube is made from Monel. The connection ends (4) and (5) of the continuous tube (3) project through openings in the jacket (1), through which cooling water from outside the furnace can circulate through the cooling panel inside the furnace and thus cool this panel. As can be seen from Fig. 3, it is possible for a plurality of continuous tubes (3) to be cast into the cooling panel (2).

The space between the jacket (1) and the cooling panel may be filled up with a casting compound (6). Attachment bolts for attaching the cooling panel to the jacket (1) from outside the furnace are not shown. This attachment method is of a traditional nature, as is customarily used in cooling panels.

Tapering ribs (7) are cast onto the furnace side of the cooling panel. These ribs (7) may be distributed over the surface of the panel in a pattern such as that shown in Fig. 5. Since the length of these ribs is limited, it will be impossible for high thermal stresses to build up in these ribs. A vertical frictional force which a downwardly moving charge may exert on the ribs can be absorbed by supporting backs (9) (cf. Fig. 2 and Fig. 5).

Solidifying crust material (8) may collect between the ribs, and if appropriate the supporting backs, forming thermal insulation between the furnace content and the cooling panel. The shape of the ribs prevents the possibility of this crust being torn off again easily by the downwardly moving charge. Furthermore, the tapering form of the ribs limits a high thermal load on the cooling panel via the ribs. As the crust (8) becomes thicker, that part of the ribs which is exposed to heat will become smaller.

If, after prolonged use of the cooling panels and/or as a result of fluctuating thermal loads on these panels as a result of highly divergent operating conditions, the cooling panels should become damaged, this damage will be limited to small cracks (13) in the vicinity of the outer edge of the ribs, as indicated in Fig. 4. It has been found that damage of this nature remains limited and certainly will not propagate into the main body of the cooling panel. Even if damage were to arise in that area as a result of extreme operating conditions, this does not lead to damage to the cast-in Monel tubes.

Fig. 3 furthermore shows how it is possible to save copper during the construction of the cooling panels by making that wall (11) of the cooling panel which faces towards the jacket (1) undulate around the tubes (3). The strength of the cooling panel can be maintained by arranging reinforcing walls (12) in the recesses formed, distributed over the height of the cooling panel.

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In a similar way, it is also possible to make that surface (10) of the cooling panel which faces towards the furnace content undulating.

The ribs (7) can be made larger or smaller depending on whether it is desired for them to penetrate more or less deeply into the furnace. Fig. 6 shows an embodiment in 5 which smaller ribs (7) with supporting backs (9) are arranged in a more tightly packed pattern.

If working under conditions in which it is possible to expect extremely high frictional forces from a downwardly moving charge, it is recommended for each rib to be provided with a multiplicity of supporting backs. In the embodiment shown in Fig. 10, four supporting backs (15-18) are arranged on each rib (14). This shape provides an additional resistance to a crust (8) which has formed being torn off.

Fig. 8 shows yet another embodiment (20) of the ribs with supporting backs. These are in the form of upright crosses.